Original Article

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Digitalization, Multinationals and Employment: An Empirical Analysis of Their Causal Relationships

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Abstract: This study measures the effects of digitalization related to Information and Communication Technologies (ICT) investment on employment and other economic variables according to firms' ownership. We present two computable general equilibrium models (with full employment and with unemployment) which differentiate two types of firms: National and foreign multinationals (MNEs). Both types of firms allow for the substitution between labour and ICT capital. We conclude that ICT investments significantly create jobs and raise real wages, GDP and welfare. The aggregate positive effects are stronger for ICT investment in national firms than in foreign MNEs although the sign of some sectoral effects can be negative. We also analyze the role of wage flexibility in this context, with the most favorable results related to scenarios where wages are more rigid for both cases, when investors are national firms or foreign MNEs. The model is applied to the case of Spain, a country with a high unemployment rate where ICT investment has been large since the mid 1990s.

Keywords: computable general equilibrium, investment, information and communications technologies, employment, multinationals
JEL Classification: C63, C68, J01, L63, L96, O14

1 Introduction

The emergence of the digital economy and Information and Communication Technologies (ICT) involves one of the breakthroughs in recent times. It affects a

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wide variety of spheres ranging from public sector and firms' operations, as well as individuals' ways of life. For example, there were an estimated 7.3 billion mobile-cellular subscriptions globally in 2016, with 3.5 billion people using the internet, of which 2.5 billion were from developing countries (World Bank 2017).

In this paper, the digitalization refers to the use of ICT for the production of goods and services. Research has shown that the spread of ICT in firms' operations is associated with economic benefits as higher productivity and lower costs (Czernich et al. 2011; Katz/Koutroumpis 2013). Besides the benefits, the transition towards a digital economy can involve the substitution of labour by ICT, and also the complementarity between labour and digital capital for new production processes. The debate on the interaction between this kind of automation and skilled and unskilled employment has been present during last decades, as Mokyr et al. (2015) or Autor (2015) present in a historical perspective.

Literature is wide on digitalization consequences on labour markets (see, for example, Acemoglu/Autor (2010) or the report by the World Trade Organization (2017: 76–103) for a survey). The empirical evidence is extensive in measuring effects according to sectors of production, labour qualifications, tasks, types of ICT investments, general vs partial equilibrium, etc. Nevertheless, it is scarce in measuring the role of firms' ownership. The aim of this article is to measure in isolation the different effects of digitalization according to firms' ownership (i. e. national firms and foreign multinationals (MNEs)). We perform this analysis in a general equilibrium framework with perfect and imperfect labour markets and allowing the substitution between labour and ICT capital for both types of firms. For that purpose, we study the Spanish case with these two types of firms which have different cost structures within each sector of the economy. The high unemployment rate in the Spanish economy is relevant in order to simulate the potential complementarity of labour with digital capital and not only the substitution effect in a general equilibrium framework.

We thus will use a computable general equilibrium (CGE) model which considers the presence of multinationals to measure the impact of investment flows linked to ICT. The use of this methodology allows us to consider sectoral (or microeconomic) effects together with the overall outcomes at the macroeconomic level in a unified framework. This is important since productivity may displace workers in some sectors, but spillovers related to final demand through lower goods prices and income effects due to changes in factor rents can improve it in some sectors (as noted by Gregory et al. (2016)). Thus, an economy-wide coverage of the impact of digitalization seems in order to assess its general equilibrium impact and not many CGEs have included the presence of multinationals, (see Latorre 2009, for a review).

A general equilibrium framework is appropriate because technological progress may have ambiguous effects on aggregate employment, but affect the employment sectoral composition. Higher productivity could arguably reduce jobs. The same can be said about the presence of the rather capital-intensive technologies of foreign MNEs. The latter have been found to be more capital intensive than national firms operating in the same sector (e. g. Latorre/Gómez-Plana 2011). Their capital-intensive technologies could also reduce labour demand when more investment inflows come in. For that reason, the paper presents the economic effects from digital investment according to the ownership of the firms: national or foreign. We extend the model of Gómez-Plana/Latorre (2014), using several assumptions about wage rigidity (with unemployment), as well as a full labour employment scenario in order to offer a rich assessment of possible labour market effects. We aim at offering evidence on this under researched area of CGE evaluations of the impact of ICT.

The rest of the paper is organized as follows. The next section offers an overview of the recent evolution of ICT investment inflows. In Section 3 we explain the model, while Section 4 explains the calibration and data sources. The description of the simulations and macro and microeconomic results are discussed in the next two sections. Section 7 develops a sensitivity analysis of the results. The main conclusions close the paper. There are also two Appendixes. The first one fully describes the equations, variables and parameters of the model. Sectoral definitions and correspondences across the different classifications used are available in the second one.

2 ICT investment in the Spanish economy

We present an overview of the ICT investment in Spain in the context of total investment or Gross Fixed Capital Formation (GFCF). For an approach to investment in the Spanish economy, see Mas et al. (2015) and Serrano et al. (2017). They estimate a time series for the investment flows and stocks for Spain (see Section 4 for a description). The database covers from 1964 to 2014 distinguishing between 18 investment assets at aggregate and sectoral level.

The evolution of Spanish aggregate GFCF from 1965 to mid-1990s has two different phases. From 1960s to 1984 the GFCF remained stable and even had a light decrease, but it followed a period of GFCF expansion from mid 1980s to early 1990s. The recession that affected the Spanish economy between 1992 and 1993 depressed GFCF, and it was followed by an intense expansion until 2007 (with the exception of year 2000, influenced by the Dot-Com bubble). During

this long expansion, the GFCF growth rate was closer to the most dynamic Asian countries than to the Western countries rates.[1] In 2007, the peak of the times series, GFCF was 30.7 % of GDP, and it was 24 % on average for the time interval 1964–2014. The Great Recession lowered this ratio, basically for the sinking of dwellings and other construction.

The focus in this paper is the digital capital that is suitable to replace labour in the short and medium term. This includes several types of GFCF assets as investments in ICT (Office equipment and hardware, Communications, Software), Machinery and mechanic equipment and, to a certain extent and Intangible assets (see below). Figure 1 shows the change in the real Net Capital Stock[2] for those assets since 1995. It also incorporates the Total GFCF. As explained above, the aggregate GFCF evolution in Spain had its relevant momentum at mid-1990s but not before, and the same can be said on ICT investments. Hence, Figure 1 shows that the most relevant growth rates have been in ICT assets and Other intangible assets.

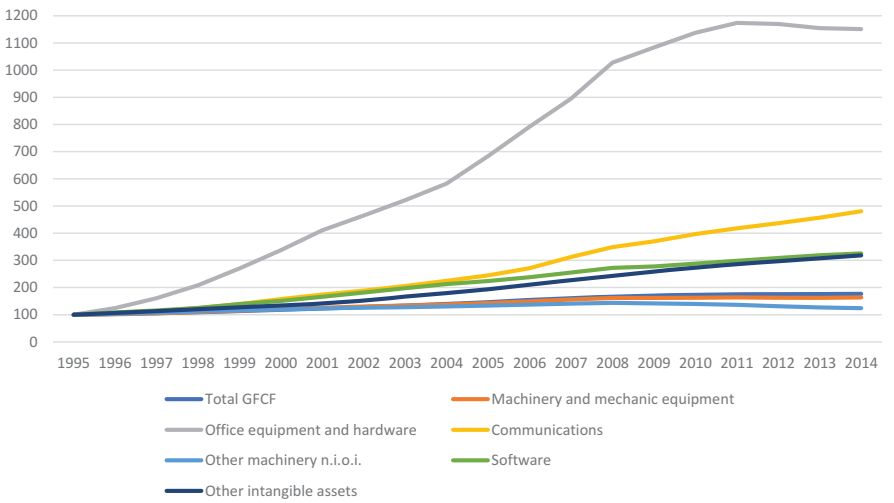

Figure 1: Net Capital Stock (1995 = 100).
Source: Fundación BBVA (2017).

1 For example, the 2000–2011 average ratio GFCF/GDP was 26.8 % for Spain and 16.3 % for UK, 18.1 % for Canada, 18.2 % for USA, 18.4 % for Germany, 19.5 % for France, 28 % for South Korea or 30.1 % for India (Mas et al. 2013).

2 Net Capital Stock is the stock of assets surviving from past periods, corrected for depreciation (OECD 2009).

The empirical research presented below has its benchmark in 2005 and simulates the change in digital capital for the period 2005 to 2014. This includes the Great Recession, which had a very relevant effect on GFCF. Nevertheless, as displayed in Figure 2, it is noteworthy that while Total GFCF grew 21%, Communications growth had a 96.2% rate, Office equipment and hardware grew 68.3%, Software 45.3% and Other intangible assets 64.4%. Hence, the most dynamic side of investment during the crisis was related to digital capital.

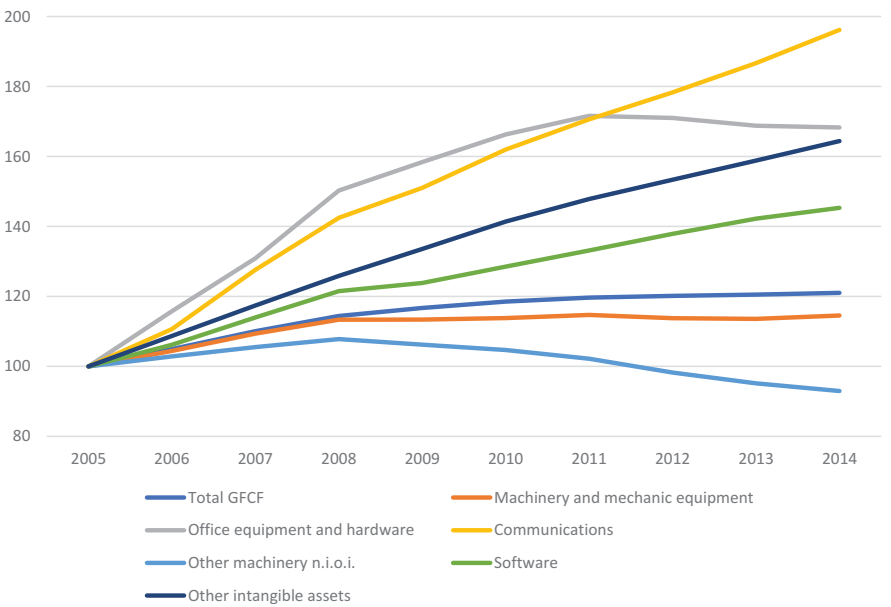

Figure 2: Net Capital Stock (2005 = 100).
Source: Fundación BBVA (2017).

The sectoral effect is reflected in Table 1. As shown in column 7, most of the 25 sectors (except 4) show a positive 2005–2014 change in the ICT Net Capital Stock. Three of the sectors with a negative change in ICT investment are the most depressed sectors during the Great Recession: Construction (–29.83%), Financial intermediation and Activities auxiliary to financial intermediation (–5.50%). The other one is Electronics (–17.67%). It is noticeable that manufactures had lower positive growth rates than services. The share of ICT assets on Total Capital Stock (column 3) has a wide sectoral variance: from 0.04% in Real estate activities, to 34.23% in Computer and related activities.

Table 1: Net Capital Stock and ICT Capital Stock across sectors in Spain (thousands of €).

	2005			2014			2005-2014
	Net Capital Stock (1)	ICT Capital Stock (2)	Share (%) (3) = (2) / (1)	Net Capital Stock (4)	ICT Capital Stock (5)	Share (%) (6) = (5) / (4)	Growth ICT Capital Stock (%) (7) = (5-2) / (2)
1.Primary goods	52907646.0	94909.9	0.18	55416580.42	138945.744	0.25	46.40
2.Energy	118135812.8	3535480.1	2.99	200060841.6	9643473.44	4.82	172.76
3.Food products	43672271.2	1565447.7	3.58	54425472.24	2782223.08	5.11	77.73
4.Beverages & Tobacco	43672271.2	1565447.7	3.58	54425472.24	2782223.08	5.11	77.73
5.Textiles products	10951207.1	490016.4	4.47	7585541.864	659352.324	8.69	34.56
6.Chemical products	20094782.1	769975.6	3.83	24443638.53	1129273.34	4.62	46.66
7.Basic metals	45167709.2	1581740.4	3.50	43988211.84	2244264.53	5.10	41.89
8.Manufacture of metal products	45167709.2	1581740.4	3.50	43988211.84	2244264.53	5.10	41.89
9.Electronics	11792764.6	612816.8	5.20	10054572.32	504513.466	5.02	-17.67
10.Motor vehicles, trailers & semi-trailers	22496546.2	1029236.8	4.58	15267511.16	1666493.63	10.92	61.92
11.Other industries	75022803.3	2809294.1	3.74	70155477.75	4200799.43	5.99	49.53
12.Contruction	342575361.1	1009295.8	0.29	386517278.3	708261.702	0.18	-29.83
13.Sale & repair of motor vehicles	119066489.9	4969786.7	4.17	159631914.3	10286315.6	6.44	106.98
14.Wholesale and retail trade	119066489.9	4969786.7	4.17	159631914.3	10286315.6	6.44	106.98
15.Air and water transport	138759514.2	6278026.1	4.52	173513223.9	11116783.5	6.41	77.07
16.Other transport	138759514.2	6278026.1	4.52	173513223.9	11116783.5	6.41	77.07
17.Telecommunications	66940496.5	14691440.7	21.95	73834984.49	20538109.8	27.82	39.80
18.Financial intermediation	38119323.4	6804524.1	17.85	58506882.48	6430194.71	10.99	-5.50
19.Activities auxiliary to financial intermediation	38119323.4	6804524.1	17.85	58506882.48	6430194.71	10.99	-5.50
20.Real estate activities	1206481283.5	458514.8	0.04	1442642626	1534735.52	0.11	234.72
21.Renting of machinery & equipment	15154327.3	1426025.1	9.41	20554245.86	3543135.3	17.24	148.46
22.Computer and related activities	7834112.4	2681945.6	34.23	10220366.58	5729768.12	56.06	113.64
23.Other business activities	50734052.2	4774083.9	9.41	68812040.5	11861800.8	17.24	148.46
24.Other services	214931811.9	7425231.1	3.45	279136464.2	15449629	5.53	108.07
25.Public services	279388864.7	5704220.8	2.04	330098628.5	9811665.31	2.97	72.01
TOTAL	2880227179.5	68712012.4	2.39	3484866503	119979738	3.44	74.61

Source: Own elaboration from Fundación BBVA (2017).

Our approach introduces ICT as investments in the economy, although the ICT current expenditure is also considered as intermediates used across sectors. Corrado et al. (2016) illustrate the importance of this approach when they explain that identifying ICT with intermediates alone underestimates the contribution of ICT to productivity and growth. This arises from the fact that GDP, which is the sum of value added generated across sectors, is calculated subtracting intermediates from production values. By contrast, if we consider ICT as investments, it will contribute to the GDP of the economy since it is capital additional to the benchmark capital endowment. One of the problems to evaluate the impact of ICT is the lack of good measures of its evolution. Again, this is illustrated more broadly for the concept of intangibles by Haskel/Westlake (2017). They note that some investment in intangibles does "*not appear in company balance sheets and national accounts because accountants and statisticians tend not to count intangible spending as an investment, but rather as day-to-day expenses*" (p. 240). While there are markets in which prices of tangibles can be proxied, "*there is no market where you can see the raw value of (...) investment in developing better software or redesigning its user interface*" (p. 8). Furthermore, they emphasize the nature of intangible investments differs considerably from the one of tangible investments.

3 The model

The two models in this paper extend an earlier contribution on this methodology (Gómez-Plana/Latorre 2014). One represents full employment and the other includes unemployment. They are static CGE models describing an open economy, disaggregated in 25 productive sectors, one representative consumer, the public sector and a foreign sector representing the rest of the world. The main extensions with respect to standard CGE models (see, e. g. Shoven/Whalley 1992; Dixon/Jorgenson 2013; or Burfisher 2016) are: (i) specific capital in several levels as a factor of production; (ii) ICT capital is detached from other capital (hereafter named non-ICT capital) in the production function; (iii) the modelling of the foreign MNEs, whose use of primary factors and intermediate inputs differ from national corporations; and (iv) unlike the common assumption of full employment in the labour market (used in one version of the model), another model includes unemployment in a way derived from wage curve models (Blanchflower/Oswald 1990, 1994), due to the high unemployment rate registered in the Spanish economy. In addition, the choice of the productive sectors represented in the model has been the result of a careful selection.

In the rest of this section we provide a short description of the model. The full set of equations, together with the complete list of the endogenous and exogenous variables and parameters of the model, are shown in the Appendix 1.

3.1 Equilibrium conditions

The equilibrium of the model is defined by a set of prices and an allocation of goods and factors. It involves the simultaneous solution of three sets of equations:

- Zero-profit conditions.
- Market clearing in goods and factor markets. One version of the model includes labour unemployment and another version assumes full labour employment.
- Constraints on disposable income (i. e. total revenue must equal total expenditure), labour market (in the model that includes unemployment), public sector constraints, and macroeconomic closure of the model.

3.2 Firms and production

Production is based on a technology characterized by a nested structure of intermediate inputs, several types of capital and labour. The firms' decision problem is to maximise profits subject to the technology constraints, obtaining the unit cost functions, which are further used in the zero-profit conditions. In turn, the demands for factors and intermediate inputs are obtained from Shephard's lemma on cost functions, and then used in the market-clearing equations.

Firms show constant returns to scale in their technologies and fix a competitive pricing rule, with free entry and exit of firms. Figure 3 shows the nested structure of firms' technology in sector *i*. This is a three-level technology. The first nest is a Leontief function over intermediate inputs and a composite of labour and capital, where several types of indirect taxes can be levied on intermediate inputs. The second nest is a CES function representing a composite over non-ICT capital and an aggregate of labour and ICT capital. The third nesting level is a CES between ICT capital and labour, where social contributions are levied on labour. The capital belonging to national firms is different from the foreign MNEs' capital.

However, note that within each sector there are two different varieties of the same good: a national variety produced by national firms and a foreign one produced by foreign MNEs. The price of these two varieties can differ because their costs of production vary between national firms and foreign MNEs of the same sector. Thus, we abandon the equal-costs assumption for national firms and foreign MNEs across sectors, which is present in most of the CGEs

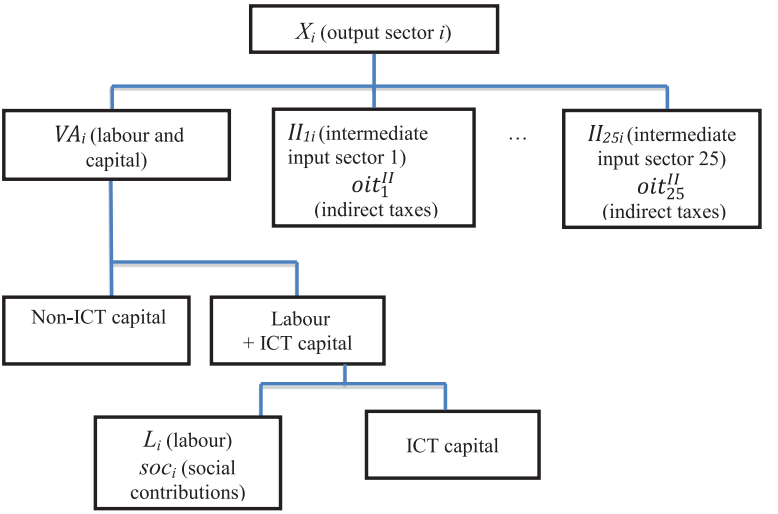

Figure 3: Production function nests for each type of firm.

including MNEs[3] (e. g. Petri et al. 2012; Petri/Plummer 2016; Ciuriak et al. 2016). In our case, the intermediate input mix is the same between both types of firms within the same sector, but their labour and capital use is different. Hence, in our model, we split sectors into the two types of firms, using real data on the shares of production, labour and capital displayed at Table 2. As result, the cost structure differs between national firms and foreign MNEs in each sector.

3.3 Representative household and consumption

There is a representative consumer household that behaves as a rational consumer. The level of consumer's welfare is determined by the endowments of capital and labour jointly with exogenous net transfers paid by the public sector.

3 Introducing differences in costs based on real data is not common since it poses at least three challenges to an already complex modelling exercise: 1) As explained by Tarr (2013), the algorithm to solve the model may not properly converge. That is why some CGE models use more stylized cost structures (e. g. Latorre/Yonezawa 2018; Latorre et al. 2018; Latorre 2016). 2) Lack of data: the detailed information needed is only available for some European countries, for Japan and, in general, with less sectoral detail for the US. To the best of our knowledge the most detailed differentiation has been undertaken by Latorre/Hosoe (2016). They not only differentiate between contributions to production, labor and capital intensity, as we do within each sector, but also include differences in the share of imported intermediates and export orientation. 3) Not all general equilibrium available software allow to model increases in capital across particular individual sectors.

Table 2: Foreign MNEs' shares in production, remuneration of employees and rental rate of capital in Spain (2005).

	Production	Remuneration of employees	Rental rate of capital
1.Primary goods	4.00	2.00	4.00
2.Energy	18.00	12.00	13.00
3.Food products	14.00	15.00	18.00
4.Beverages & Tobacco	13.00	14.00	15.00
5.Textiles products	3.85	4.00	3.00
6.Chemical products	38.00	40.00	43.00
7.Basic metals	4.00	4.00	5.00
8.Manufacture of metal products	7.00	6.00	7.00
9.Electronics	38.00	27.00	26.00
10.Motor vehicles, trailers & semi-trailers	75.83	66.68	63.27
11.Other industries	16.00	15.00	14.00
12.Contruction	1.00	2.00	1.00
13.Sale & repair of motor vehicles	21.64	9.66	35.97
14.Wholesale and retail trade	16.00	14.00	14.00
15.Air and water transport	11.00	10.00	9.00
16.Other transport	4.00	4.00	2.00
17.Telecommunications	16.64	9.99	13.41
18.Financial intermediation	10.00	8.00	4.00
19.Activities auxiliary to financial intermediation	10.00	8.00	4.00
20.Real estate activities	2.82	3.07	2.98
21.Renting of machinery & equipment	27.56	16.96	34.22
22.Computer and related activities	44.00	36.00	32.00
23.Other business activities	9.73	13.20	4.74
24.Other services	3.00	3.00	2.00
25.Public services	0.00	0.00	0.00

Sources: INE (2013b), Eurostat (2012) and OECD (2012).

The fixed endowment of labour should be interpreted as a maximum supply of labour since leisure (and unemployment in some versions of the model) is assumed to be endogenous. Hence, labour supply would be elastic up to the endowment constraint. The fixed endowment of capital is supplied to all sectors except to Public services, which only utilizes public fixed capital consumption.

The household's decision problem consists of choosing an optimal consumption bundle, by maximizing a nested utility function subject to the budget constraint. As shown in Figure 4, preferences are represented by a nested utility function on (consumption of) goods, leisure and savings. Notice that, given our static approach, we consider a unit elasticity of substitution between savings and (consumption of) goods (Howe 1975), so that savings can be interpreted as the purchase of bonds for future consumption. The representative consumer

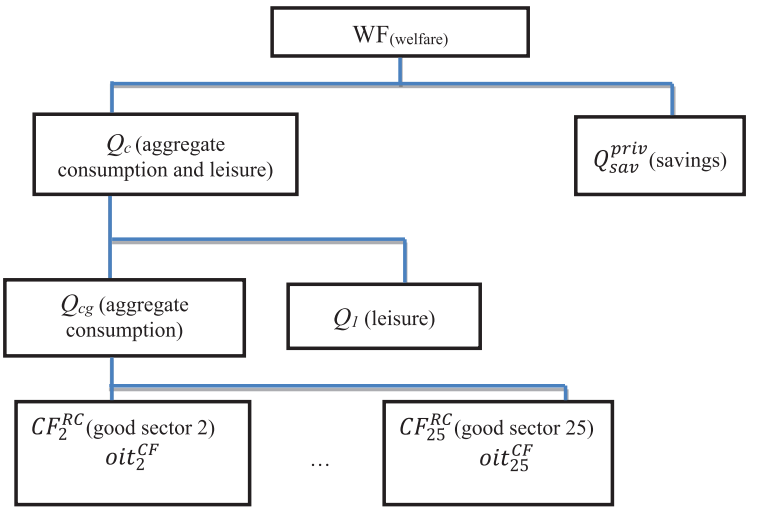

Figure 4: Welfare function nests.

buys all the final consumption goods, but the good from sector Public services. Goods can be subject to several types of indirect taxes.

The budget constraint includes total factor rents, including all the capital income for MNEs, jointly with exogenous net transfers paid by the public sector. Demand functions for goods, leisure and savings are derived from the first-order conditions and are included in the goods and factor markets equations, as well as in the macroeconomic closure for savings.

3.4 Public sector

The role of the public sector in the model is twofold, i. e. it is an owner of resources (e. g. from its capital endowment and tax revenues), and a purchaser of certain goods. We deal with these two functions in turn.

As an owner of resources, public sector's wealth includes income from capital rents, tax revenues, and net transfers from the representative household. Capital rents of the public sector include, by definition (see Eurostat 2013), the fixed capital consumption because the net operating surplus is zero for the public sector. The fixed capital consumption has been assigned to sectors Other services and Public services. All capital in Public services is owned by the public sector, whereas in Other services some capital is publicly owned and the rest is private, according to National Accounts data (see Section 4). Taxes

consist of social contributions paid by both employers and employees and net indirect taxes. All of them have been modelled using actual *ad valorem* rates calibrated from benchmark data, with an endogenous revenue level. The rest of taxes have been modelled as exogenous.

The public sector also enters the model as a purchaser of goods. Public sector expenditure includes both market (i. e. output that is disposed of in the market at economically significant prices) and non-market goods (i. e. output that is provided at prices that are not economically significant).

3.5 Foreign sector

The model incorporates the small open economy assumption, meaning that the country faces a perfectly elastic export supply function. There is also a constant elasticity of transformation function between national and foreign sales. Regarding imports, we assume that goods are differentiated according to their origin (i. e. national or foreign), following Armington's assumption (Armington 1969), which allows for the possibility of intra-industry trade despite the assumption of exogenous world prices.

The foreign sector is closed by assuming that the difference between receipts and payments from the rest of the world is exogenous. This constraint would avoid, e. g. a permanent increase in exports with no change in imports, an unlikely scenario since it would involve an unlimited capital inflow to the country. However, this requires a matching movement in trade flows.

3.6 Factor markets

Two factors enter into the model: capital and labour. Regarding capital, both the private and the public sector own fixed endowments. Capital rents adjust to clear the national capital market, under the assumptions of capital international immobility, and no mobility across national sectors nor types of firms. Capital is specific in three levels, i. e. each sector employs different specific capital, and capital is also differentiated according to ownership (i. e. national and foreign) and type of assets (ICT and non-ICT).

The only owner of labour is the representative household. The demand for leisure is derived from the household's optimization problem. Hence, labour supply (i. e. the labour endowment less the demand for leisure) would be elastic up to the fixed amount of labour. Labour is assumed to be internationally immobile, but mobile across national sectors.

There are two versions of the model with respect to labour. The first one is the standard perfect competition labour market. In addition, we assume a second version based on the wage equation (Blanchflower/Oswald 1990, 1994). It has been used in CGE models; see, e. g. Rutherford et al. (2002). Accordingly, the model includes the following constraint:

$$\frac{W}{CPI} = \left(\frac{1-U}{1-\overline{U0}}\right)^{\frac{1}{\beta}}$$

where *W/CPI* denotes the real wage, *U* is the unemployment rate, $\overline{U0}$ is the unemployment rate in the benchmark, and β is a nonnegative parameter that measures the sensitivity of real wages to the rate of unemployment. Thus, as β approaches infinity, the real wage approaches its benchmark value (which is 1 according to the calibration process explained below): this is the case of rigid real wages when wages do not change when unemployment does. At the other extreme, as β approaches zero, the unemployment rate approaches its benchmark value, with real wages being flexible. Other intermediate values for β would mean different flexibility levels of real wages to the unemployment rate.

3.7 Macroeconomic closure

Total investment is split into sectoral gross capital formation using a fixed-coefficients Leontief structure (Dervis et al. 1981). Notice that, in our static framework, total gross capital formation affects the economy as a component of final demand. The model embodies a macroeconomic closure equation stating that investment and savings (private, public, and foreign) are equal.

Finally, the model is solved as explained in Rutherford (1999), with the general equilibrium model defined as a mixed complementarity problem (see Mathiesen 1985). The software used in the empirical application is GAMS/MPSGE.

4 Calibration and data

The model has been calibrated using Spanish data. The calibration method is based on a benchmark equilibrium corresponding to the National Accounts, MNEs data, GFCF data and a set of exogenous parameters. A detailed explanation of the calibration method can be found in Mansur/Whalley (1984) and Dawkins et al. (2001).

To build the Social Accounting Matrix (SAM), we depart from the 2005 Input-Output symmetric table available for the Spanish economy.[4] In order to do so we further use the institutional sectors accounts from the Spanish National Statistics Institute (Instituto Nacional de Estadística 2012). Public revenue data have been disaggregated into net indirect taxes and Social security contributions while the rest of taxes are exogenous. The 25-sector disaggregation in the SAM, from the 72 sectors of the Input-Output table, are the ones that have already been presented in Table 1.

The source data to estimate the different production variables for national firms and foreign MNEs comes from Eurostat (2012), Instituto Nacional de Estadística (2013) and OECD (2013). Results are displayed in Table 2.

The source for estimations of ICT and non-ICT capital and the changes in investment is Fundación BBVA (2017). Its methodology is described in Serrano et al. (2017) and OECD (2009). This database is also used by the project EU KLEMS or by OECD (Structural Analysis Database, STAN; Productivity Database, PDB; Productivity Database by Industry, PDBi). It uses GCFC provided by the Spanish National Statistics Institute, and measures investment with specific price indexes for each investment asset. Year 2005 is taken for the benchmark equilibrium. We calculate the growth in ICT capital from 2005 data to the most recent year (i. e. 2014) for the growth in ICT capital. The sectoral ICT investment assets have been adapted to our sectoral classification, shown in Appendix 2, and they includes Office equipment and hardware, Communications and Software. The variable to proxy capital endowment is the Net Capital Stock.

The choice of elasticities plays a key role in the model and for that reason there is a sensitivity analysis of the results in Section 7. The benchmark values for those elasticities are:

- Elasticities of substitution in the welfare function:
  - between consumption and savings: 1.
  - between final consumption and leisure: 1.
  - across final consumption goods: 1.

4 Data are for the year 2005 and are based on a Social Accounting Matrix constructed using a symmetric input-output table of Spain. A more recent Symmetric Input-Output table is available, but the deep crisis in Spain in 2010 (e. g. unemployment rate was 19.86 %, while it was 9.15 % in 2005) was a critical point for this selection. Many adjustments have taken place at macroeconomic and microeconomic level in the Spanish economy. In addition, we model ICT investment accruing from 2005 till 2014, which allows grasping nearly a decade of investment related to the digital economy. Those arguments have been considered relevant to discard the 2010 Input-Output Table.

- Elasticities related to production:
  - between intermediate inputs and value-added composite: 0.
  - between non-ICT capital and composite of ICT capital and labour: 1.21.
  - between labour and ICT capital: 1.13 (for the model with full-employment labour market) and 1.09 (for the model with labour market with unemployment).
  - between national and foreign goods (Armington elasticities): sectoral values fluctuate between 0.70 and 2.90.
  - between goods sold in the national market and abroad (elasticities of transformation): sectoral values fluctuate between 1.90 and 4.30.

The elasticity of substitution between ICT capital and labour is from Carbonero et al. (2017). They estimate the elasticity for the European Union (EU-15) in two labour market frameworks: competitive and with market imperfections where there is a matching between vacancies and workers. Their estimates are statistically different from one and they find that the EU members with higher share of routine occupations (as Spain) tend to have larger elasticities. The source for the elasticity of substitution between non-ICT capital and composite of ICT capital and labour is Raurich et al. (2012) who find a value higher than one consistent with Spanish data for substitution between capital and labour. The literature sources for the rest of the elasticities are Narayanan/Walmsley (2008) for Armington elasticities; de Melo/Tarr (1992) for the elasticities of transformation; and the elasticity of substitution between consumption and leisure is consistent with the survey by Ballard/Kang (2003). The rest of values are common in the literature.

5 Simulations

We simulate the entry of ICT investment in the Spanish economy departing from a calibrated equilibrium for the year 2005. There are two types of simulations: (a) National firms are responsible for all the new ICT investment; (b) foreign MNEs are responsible for all the new ICT investment. There is no data to divide the ICT investments according to firms' ownership. For that reason, we take these two extreme simulations. The size of the shock is modelled in two ways: (1) The shock includes the real change in ICT assets between 2005 and 2014, as reflected in column 7 at Table 1; (2) the shock is a 1% increase across sectors in ICT Capital Stock.

The previous simulations will allow to weight the role of the two types of firms according to ownership. Key points in the simulation are the roles of the high unemployment rate and the wage flexibility when the investment becomes part of the capital of the sectors. Hence, the results try to show the effects of ICT investment on macro and microeconomic variables isolated from other changes that took place at the same time.

5.1 Definition of scenarios

Simulations have been performed under six labour market scenarios, where the first five involve a labour market with unemployment, and the last one displays a perfect competition labour market. Specifically, these scenarios are:

(i) A very rigid real wage with respect to unemployment rate ($\beta = 20$).
(ii) A rigid real wage with respect to unemployment rate ($\beta = 3$).
(iii) A **Reference scenario** with a plausible sensibility of real wage with respect to unemployment rate ($\beta = 1.5$).
(iv) A flexible real wage with respect to unemployment rate ($\beta = 0.1$).
(v) A very flexible real wage with respect to unemployment rate ($\beta = 0.001$).
(vi) No unemployment.

6 Empirical results

The results from the above simulations on the main variables appear in Tables as percentage changes from benchmark, except for the unemployment rate, in which case changes are also expressed as percentage points.

6.1 Macroeconomics results

The impact on the main macroeconomic variables appears in Table 3. The variables displayed are Gross Domestic Product (GDP), real wages, employment, unemployment rate and welfare (the Hicksian Equivalent Variations index). Panel A offers the impact of the *actual levels of ICT Capital Stock growth for the period 2005–2014*. Panel B displays the impact of a *1% change in the ICT Capital Stock*. Both cases are expansionary in macroeconomic terms, motivated by the increase in capital endowment. Hence, we can forecast *ex-ante* that new capital can substitute labour and/or complement it.

Table 3: Simulation results: Macroeconomic impact of the change in ICT Capital Stock (%).

	GDP	Real wages	Employment	Unemployment rate		Welfare
				(%)	(p.p)	
Panel A. Shock: Real 2005–2014 change in ICT Capital Stock						
VERY RIGID WAGES (β = 20)						
National firms	2.27	0.18	1.6	−16.3	−1.49	2.27
Foreign MNEs	0.84	0.1	0.69	−6.88	−0.63	0.98
RIGID WAGES (β = 3)						
National firms	1.68	0.48	1.09	−11.11	−1.02	1.85
Foreign MNEs	0.72	0.22	0.48	−4.69	−0.43	0.8
REFERENCE SCENARIO (β = 1.5)						
National firms	1.52	0.65	0.8	−8.08	−0.74	1.6
Foreign MNEs	0.65	0.29	0.35	−3.41	−0.31	0.7
FLEXIBLE WAGES (β = 0.1)						
National firms	1.15	1.05	0.1	−0.93	−0.09	1.01
Foreign MNEs	0.5	0.46	0.06	−0.4	−0.04	0.46
VERY FLEXIBLE WAGES (β = 0.001)						
National firms	1.1	1.11	0.01	−0.01	0.00	0.93
Foreign MNEs	0.48	0.49	0.02	−0.004	0.00	0.41
FULL EMPLOYMENT						
National firms	1.09	1.07	−0.02			0.93
Foreign MNEs	0.48	0.48	0.01			0.42
Panel B. Shock: 1 % change in ICT Capital Stock						
VERY RIGID WAGES (β = 20)						
National firms	0.044	0.003	0.038	−0.385	−0.035	0.051
Foreign MNEs	0.042	0.003	0.035	−0.362	−0.033	0.049
RIGID WAGES (β = 3)						
National firms	0.038	0.01	0.026	−0.262	−0.024	0.041
Foreign MNEs	0.036	0.009	0.024	−0.247	−0.023	0.039
REFERENCE SCENARIO (β = 1.5)						
National firms	0.034	0.014	0.019	−0.191	−0.017	0.035
Foreign MNEs	0.033	0.013	0.018	−0.179	−0.016	0.034
FLEXIBLE WAGES (β = 0.1)						
National firms	0.025	0.023	0.002	−0.022	−0.002	0.022
Foreign MNEs	0.024	0.022	0.002	−0.021	−0.002	0.021
VERY FLEXIBLE WAGES (β = 0.001)						
National firms	0.024	0.024	0	0	0.000	0.02
Foreign MNEs	0.023	0.023	0	0	0.000	0.019
FULL EMPLOYMENT						
National firms	0.024	0.023	0			0.02
Foreign MNEs	0.023	0.0232	0			0.019

The effects on GDP, employment and welfare are going to be positive and unemployment would decrease. The magnitude of the changes is higher for the national firms' investment in ICT assets than for foreign MNEs investment. Also, the higher the wage rigidity, the larger the positive effects in employment, GDP and welfare. The change in GDP is addressed by changes in factor employment (i. e. capital and employed labour) and in factor prices. With respect to capital, its contribution to GDP growth through the expansion in capital endowment was compensated with the fall in the real capital rent. In fact, this price fall took place in Spain for ICT assets with respect to other components of GFCF (see Mas et al. 2015: p. 12). This is a worldwide effect due to the decline of the price for computer and digital equipment. With respect to labour, the GDP increases due to both the increase in employment (i. e. lower unemployment and leisure) and the increase in real wages. This overall positive effect in GDP is especially relevant in the scenarios with more rigid wages where the real wage moderation generates larger employment growth than with more flexible wages. Notably, the increase in labour productivity due to the new ICT capital always generates wage increases, although when wages are more flexible, the workers benefit more from wage gains, than from new jobs.

In order to disentangle the role of firms' ownership in the effects, the 1 % shock clarifies that the positive effect of ICT investment is always higher if it is a national firm's investment. In all scenarios, with flexible or rigid wages, with unemployment or with full employment, the positive effects on GDP, real wages, employment, unemployment rate and welfare are larger if ICT investment is accomplished by national firms. The main characteristics of the labour market (i. e. wage rigidity or flexibility) are relevant for the size of the effect, but not for the prevalence of national firms' ICT investment effects. The panel A showing the real 2005–2014 shock also displays a much higher effect of national firms versus foreign MNEs, but the asymmetric sectoral shock (i. e. the size of the shock is presented in column 7 at Table 1) could interfere in this result. From the comparison of the two panels another conclusion can be inferred: if real 2005–2014 ICT investment flows would be done by national firms, the gains for the Spanish economy as a whole (in terms of GDP, employment, real wages, unemployment and welfare) should be around twice the gains if the ICT investment is performed by foreign MNEs. The rationale is that foreign MNEs are more capital intensive, and the labour productivity gains derived from the shock are lower.

If we proxy the changes in employment for the *Reference scenario* with the data for Spain from the Labour Force Survey and National Accounts, we can conclude that a 1 % growth in ICT investment in all sectors executed by national firms would increase employment by 3649 jobs (0.019 %). The change would be

3457 jobs (0.018 %) when foreign MNEs are the investors. The change in GDP would be 316.4 millions of euros and 307.1 millions, respectively.

Those results, even generated by simulation, support that the assertion "*MNEs are not only outgrowing firms in all other industries, but also disrupting traditional patterns of job creation*" (UNCTAD 2017, p. 159) would be true for the Spanish case, assuming that national firms are performing closer to those traditional patterns. Moreover, "*although Tech MNEs are creating more employment as they grow, sources of corporate value are shifting from labour to capital*" and "*this [MNEs'] employment creation is (...) significantly lower than the increase in total assets*" (ibid., p. 162) are compatible with our results. Even, the role of intangibles (see Section 2) is more prominent in large MNEs and "*the focus is moving toward capital components such as intangibles and cash, which generate relatively little employment*" (ibid., p. 162).

6.2 Microeconomic results

Next, we present in Table 4 he results across sectors for the two most relevant variables, namely, employment and output (in physical units) and we also analyse the goods demand side through final consumption (in real value). In order to interpret these sectoral results, it is necessary to take into account the constraints the model imposes on productive factors, i. e. labour is modelled under an unemployment rule in five scenarios and leisure can take place in all scenarios, but capital is assumed fully employed and specific at three levels: sector, ownership (i. e. national/foreign) and type of asset (i. e. ICT/Non-ICT). Notice also that in a general equilibrium framework the results can be driven by several forces which, in some cases, move in opposite directions.

We provide in Table 4 an overview of the evolution of both production and employment across sectors, with the *Reference scenario*, which uses a central value for the elasticity of wage adjustment ($\beta = 1.5$). The size of the real shock 2005–2014 is not positive for all the sectors, as seen in Table 1. Electronics, Construction, Financial intermediation, and Activities auxiliary to financial intermediation share a negative ICT capital flow, although we have modelled for them a zero change to avoid the potential negative use of capital as input. Nevertheless, we do not observe a large positive nor negative correlation between change in capital (column 7 in Table 1) and change in labour at sectoral level (first two columns in Table 4). The non-weighted correlations are −0.14 for national investment and −0.15 for the foreign one. The overall effect is job creating (see Table 3) showing complementarity, but also those small negative correlations show that substitution is taking place.

Table 4: Simulation results (reference scenario): Employment and output effects of the change in ICT Capital Stock (%).

Panel A. Shock: Real 2005–2014 change in ICT Capital Stock

	Employment		Output		Final consumption	
	National firms	Foreign MNEs	National firms	Foreign MNEs	National firms	Foreign MNEs
1.Primary goods	0.85	0.30	0.23	0.08	1.84	0.79
2.Energy	1.81	0.42	2.69	1.42	3.48	1.57
3.Food products	0.75	0.20	1.24	0.51	1.80	0.78
4.Beverages & Tobacco	2.64	1.07	2.43	1.05	4.16	1.89
5.Textiles products	1.90	0.80	1.78	0.71	2.63	1.17
6.Chemical products	1.32	0.58	1.36	0.81	0.96	0.38
7.Basic metals	1.14	0.62	1.18	0.54	2.49	1.10
8.Manufacture of metal products	1.24	0.61	1.24	0.60	2.45	1.08
9.Electronics	1.30	0.71	0.98	0.53	2.28	1.00
10.Motor vehicles, trailers & semi-trailers	1.62	0.63	1.55	1.18	2.74	1.22
11.Other industries	1.56	0.72	1.53	0.79	2.35	1.03
12.Contruction	2.14	1.06	1.32	0.65	1.78	0.76
13.Sale & repair of motor vehicles	1.31	0.26	1.81	1.07	1.87	0.81
14.Wholesale and retail trade	0.56	0.05	1.68	0.77	1.39	0.58
15.Air and water transport	2.04	1.08	2.25	1.10	1.45	0.61
16.Other transport	0.90	0.95	1.74	0.72	1.03	0.45
17.Telecommunications	−3.85	−4.36	3.64	2.72	2.02	0.88
18.Financial intermediation	1.63	0.85	0.99	0.52	1.65	0.70
19.Activities auxiliary to financial intermediation	2.41	1.23	0.85	0.43	1.53	0.65
20.Real estate activities	3.70	1.84	0.36	0.17	1.49	0.63
21.Renting of machinery & equipment	−3.18	−3.35	2.97	2.11	2.08	0.91
22.Computer and related activities	−6.69	−8.52	4.43	4.28	2.21	0.97
23.Other business activities	−0.92	0.60	1.99	1.00	2.05	0.95
24.Other services	1.27	0.69	1.47	0.54	1.58	0.69
25.Public services	0.11	0.06	0.05	0.02	0.23	0.09
Max	3.701	1.841	4.431	4.277	4.164	1.889
Min	−6.690	−8.524	0.054	0.023	0.233	0.086
Variance	4.804	4.686	0.966	0.785	0.609	0.131
Range	10.390	10.365	4.377	4.254	3.930	1.803

(*continued*)

Table 4: (*continued*)

Panel B. Shock: 1 % change in ICT Capital Stock						
	Employment		Output		Final consumption	
	Domestic firms	Foreign MNEs	Domestic firms	Foreign MNEs	Domestic firms	Foreign MNEs
1.Primary goods	0.019	0.020	0.005	0.006	0.041	0.039
2.Energy	0.072	0.065	0.036	0.044	0.074	0.072
3.Food products	0.019	0.020	0.025	0.024	0.040	0.038
4.Beverages & Tobacco	0.058	0.062	0.050	0.051	0.087	0.086
5.Textiles products	0.046	0.047	0.045	0.046	0.057	0.055
6.Chemical products	0.025	0.030	0.031	0.032	0.022	0.021
7.Basic metals	0.025	0.031	0.029	0.030	0.054	0.052
8.Manufacture of metal products	0.025	0.026	0.028	0.029	0.053	0.051
9.Electronics	0.030	0.030	0.034	0.042	0.050	0.048
10.Motor vehicles, trailers & semi-trailers	0.039	0.034	0.038	0.040	0.059	0.057
11.Other industries	0.028	0.033	0.031	0.035	0.051	0.049
12.Contruction	0.042	0.043	0.027	0.027	0.039	0.038
13.Sale & repair of motor vehicles	0.034	0.034	0.036	0.038	0.041	0.040
14.Wholesale and retail trade	0.021	0.018	0.030	0.031	0.032	0.030
15.Air and water transport	0.038	0.043	0.040	0.045	0.033	0.032
16.Other transport	0.023	0.026	0.034	0.035	0.024	0.023
17.Telecommunications	−0.149	−0.223	0.097	0.130	0.044	0.043
18.Financial intermediation	−0.009	−0.040	0.066	0.074	0.037	0.035
19.Activities auxiliary to financial intermediation	−0.044	−0.088	0.098	0.143	0.034	0.033
20.Real estate activities	0.090	0.097	0.008	0.009	0.034	0.032
21.Renting of machinery & equipment	−0.010	−0.002	0.048	0.055	0.046	0.044
22.Computer and related activities	−0.080	−0.132	0.071	0.100	0.048	0.046
23.Other business activities	0.007	0.026	0.038	0.048	0.046	0.045
24.Other services	0.030	0.029	0.031	0.030	0.035	0.034
25.Public services	0.003	0.003	0.001	0.001	0.006	0.005
Max	0.090	0.097	0.098	0.143	0.087	0.086
Min	−0.149	−0.223	0.001	0.001	0.006	0.005
Variance	0.002	0.004	0.001	0.001	0.000	0.000
Range	0.239	0.321	0.097	0.142	0.082	0.081

There are several sectors with negative effect on employment: Telecommunications, Renting of machinery & equipment and Computer and related activities. Moreover, Other business activities also has a negative effect on employment when the investment is performed by national firms. All those negatively affected sectors are related with Services. Those changes are explained by changes in productivity at the sectoral level due to the entrance of capital. The case of the homogeneous shock of 1% change in ICT Capital Stock for all sectors also generates some employment negative effects more extended to Services sectors: Besides Telecommunications, Renting of machinery & equipment and Computer and related activities, also Financial intermediation and Activities auxiliary to financial intermediation have a negative employment change. In the same way, Autor et al. (2015) show for the US case that non-manufactures are more negatively affected from the incorporation of new technologies than manufactures since the 1990s. With the 1% shock, sectors as Real estate activities, Energy, Beverages & Tobacco, Textile products and Air and water transport are the most outstanding as employment generators in percentage.

In any case, although the volume of factors, labour and capital, has decreased in several sectors, all the sectors present an increase in physical output production. This increase is larger in the sectors where employment has lowered (i. e. Telecommunications, Renting of machinery & equipment and Computer and related activities for the 2005–2014 shock, and the same sectors plus Financial intermediation and Activities auxiliary to financial intermediation for the 1% shock). This means that the entrance of digital capital here would boost output with the collateral effect of reducing employment.

Finally, we provide some comments on final consumption, which is also reflected in Table 4. There is a product demand effect. The lower prices involve a raise in real income, so there is going to be an income effect with new product demand which is going to generate additional labour demand. This increase in real income would be spent in all kind of goods: form low-tech non-tradables to the rest of goods. This effect is captured in our general equilibrium model. The gain in real income (as reflected in the gain in GDP) is going to expand final consumption in all the goods, both in the real 2005–2014 shock and in the 1% shock. Gregory et al. (2016) also note that this effect depends on where the income is spent. The effect would be lower, for example, if foreign MNEs repatriate capital income to their home economies (see Latorre (2009) for an example of this type of effect of profit repatriation in a CGE context). We have assumed that all the income generated in Spain is spent following the Spanish representative household pattern of consumption, so most of the income is spent in national goods. Nevertheless, we can add a new insight: it is also relevant for

final consumption what type of firm is generating the change in income. Results in final consumption for the 1% shock display that the effect in final consumption is larger when the ICT investment is performed by national firms. The reason is that the change in goods prices benefits more the consumers when the investors are national firms.

Next, we check the role of wage flexibility in the sectoral employment creation according to the six scenarios specified, from the most rigid framework to the most flexible wages, including a full employment scenario. Tables 5 and 6 reflect the sectoral employment effects when the ICT investment is performed by national firms (Panel A) or foreign MNEs (Panel B). Table 5 groups the effects for the 2005–2014 change in ICT Capital Stock and Table 6 for the 1% change in ICT Capital Stock.

The sectoral employment changes reported in Tables 5 and 6 convey a multifaceted picture. There are wide sectoral asymmetric effects, with sectors positively and negatively affected. With respect to Panel A in Table 5, firstly, the more flexible the wages, the more sectors are negatively affected. The higher increase in wages (see Table 3) for flexible wages scenarios is behind this negative effect. It is noteworthy that the negative effect is highly concentrated in non-manufactures. For example, the negative employment effects for the full employment scenario are in nine sectors out of 25 (from the most to the least negative effect): Computer and related activities, Telecommunications, Renting of machinery & equipment, Other business activities, Energy, Wholesale and retail trade, Primary goods, Other transport and Food products. Note that most of them are related to Services. Secondly, not only the number of negatively affected sectors increases with the flexibility of wages, also the size of the negative effect rises (and it is reduced for the sectors positively affected). Thirdly, the sectoral range of the changes also decreases with the flexibility of wages, with a lower variance of the results. Finally, Panel B in Table 5 (i. e. ICT investment by foreign MNEs) shows a similar pattern with two differences: (i) The positively affected sectors have a smaller positive effect while negatively affected sectors have a larger negative effect; (ii) the eight negatively affected sectors are not exactly the same for the most flexible wages scenarios. Again, there is an employment decrease for seven sectors: Computer and related activities, Telecommunications, Renting of machinery & equipment, Energy, Wholesale and retail trade, Primary goods and Food products. But now Sale & repair of motor vehicles exhibits employment decreases, while Other business activities and Other transport now manifest employment growth.

Table 5: Simulation results: Employment effects of the 2005–2014 change in ICT Capital Stock (%).

Panel A. Investment by national firms

	Very rigid wages	Rigid wages	Reference scenario	Flexible wages	Very flexible wages	Full employment
1.Primary goods	1.96	1.26	0.85	−0.11	−0.24	−0.21
2.Energy	4.04	2.63	1.81	−0.11	−0.36	−0.77
3.Food products	1.51	1.03	0.75	0.09	0.00	−0.01
4.Beverages & Tobacco	4.19	3.21	2.64	1.31	1.13	1.09
5.Textiles products	3.25	2.40	1.90	0.73	0.58	0.58
6.Chemical products	2.30	1.68	1.32	0.47	0.36	0.34
7.Basic metals	2.28	1.56	1.14	0.15	0.02	0.02
8.Manufacture of metal products	2.18	1.59	1.24	0.43	0.33	0.33
9.Electronics	2.37	1.70	1.30	0.37	0.25	0.27
10.Motor vehicles, trailers & semi-trailers	2.95	2.11	1.62	0.46	0.31	0.30
11.Other industries	2.54	1.92	1.56	0.70	0.59	0.58
12.Contruction	2.93	2.43	2.14	1.45	1.36	1.36
13.Sale & repair of motor vehicles	2.33	1.69	1.31	0.43	0.31	0.28
14.Wholesale and retail trade	1.44	0.88	0.56	−0.21	−0.30	−0.36
15.Air and water transport	2.89	2.35	2.04	1.30	1.20	1.16
16.Other transport	1.93	1.28	0.90	0.00	−0.11	−0.16
17.Telecommunications	−2.46	−3.34	−3.85	−5.06	−5.21	−5.49
18.Financial intermediation	2.52	1.96	1.63	0.85	0.75	0.76
19.Activities auxiliary to financial intermediation	3.71	2.89	2.41	1.29	1.15	1.17
20.Real estate activities	5.66	4.42	3.70	2.00	1.79	1.79
21.Renting of machinery & equipment	−1.97	−2.74	−3.18	−4.23	−4.37	−4.62
22.Computer and related activities	−5.88	−6.39	−6.69	−7.39	−7.49	−7.84
23.Other business activities	−0.07	−0.61	−0.92	−1.67	−1.77	−1.84
24.Other services	2.22	1.62	1.27	0.44	0.33	0.32
25.Public services	0.19	0.14	0.11	0.04	0.03	0.03
Total	1.60	1.09	0.80	0.10	0.01	−0.02
Leisure	1.70	1.16	0.84	0.09	−0.01	−0.03
Max	5.66	4.42	3.70	2.00	1.79	1.79
Min	−5.88	−6.39	−6.69	−7.39	−7.49	−7.84
Variance	5.42	4.99	4.80	4.54	4.53	4.93
Range	11.54	10.81	10.39	9.40	9.27	9.63

(*continued*)

Table 5: (*continued*)

Panel B. Investment by foreign MNEs						
	Very rigid wages	Rigid wages	Reference scenario	Flexible wages	Very flexible wages	Full employment
1.Primary goods	0.76	0.47	0.30	−0.11	−0.16	−0.15
2.Energy	1.35	0.76	0.42	−0.39	−0.49	−0.66
3.Food products	0.52	0.32	0.20	−0.08	−0.11	−0.12
4.Beverages & Tobacco	1.71	1.30	1.07	0.51	0.44	0.43
5.Textiles products	1.36	1.01	0.80	0.31	0.24	0.25
6.Chemical products	0.99	0.73	0.58	0.22	0.17	0.16
7.Basic metals	1.11	0.80	0.62	0.21	0.15	0.15
8.Manufacture of metal products	1.00	0.75	0.61	0.27	0.22	0.23
9.Electronics	1.16	0.88	0.71	0.32	0.27	0.28
10.Motor vehicles, trailers & semi-trailers	1.20	0.84	0.63	0.15	0.08	0.06
11.Other industries	1.13	0.87	0.72	0.36	0.31	0.31
12.Contruction	1.39	1.18	1.06	0.77	0.73	0.74
13.Sale & repair of motor vehicles	0.69	0.41	0.26	−0.12	−0.17	−0.19
14.Wholesale and retail trade	0.42	0.19	0.05	−0.27	−0.31	−0.34
15.Air and water transport	1.44	1.22	1.08	0.77	0.73	0.72
16.Other transport	1.39	1.11	0.95	0.57	0.52	0.51
17.Telecommunications	−3.77	−4.14	−4.36	−4.87	−4.93	−5.09
18.Financial intermediation	1.23	0.99	0.85	0.52	0.48	0.49
19.Activities auxiliary to financial intermediation	1.77	1.43	1.23	0.75	0.69	0.71
20.Real estate activities	2.66	2.14	1.84	1.13	1.04	1.06
21.Renting of machinery & equipment	−2.84	−3.16	−3.35	−3.80	−3.86	−4.04
22.Computer and related activities	−8.19	−8.40	−8.52	−8.82	−8.86	−9.16
23.Other business activities	0.97	0.74	0.60	0.28	0.24	0.20
24.Other services	1.09	0.83	0.69	0.34	0.29	0.29
25.Public services	0.09	0.07	0.06	0.03	0.02	0.02
Total	0.69	0.48	0.35	0.06	0.02	0.01
Leisure	0.70	0.47	0.33	0.02	−0.02	−0.01
Max	2.66	2.14	1.84	1.13	1.04	1.06
Min	−8.19	−8.40	−8.52	−8.82	−8.86	−9.16
Variance	4.80	4.72	4.69	4.64	4.63	4.95
Range	10.85	10.54	10.37	9.95	9.89	10.22

Table 6: Simulation results: Employment effects of a 1% change in ICT Capital Stock (%).

Panel A. Investment by national firms

	Very rigid wages	Rigid wages	Reference scenario	Flexible wages	Very flexible wages	Full employment
1.Primary goods	0.045	0.029	0.019	−0.003	−0.006	−0.006
2.Energy	0.124	0.091	0.072	0.027	0.021	0.016
3.Food products	0.037	0.025	0.019	0.003	0.001	0.001
4.Beverages & Tobacco	0.094	0.071	0.058	0.027	0.023	0.022
5.Textiles products	0.077	0.057	0.046	0.018	0.015	0.014
6.Chemical products	0.048	0.034	0.025	0.005	0.002	0.002
7.Basic metals	0.052	0.035	0.025	0.002	−0.001	−0.001
8.Manufacture of metal products	0.047	0.033	0.025	0.006	0.003	0.003
9.Electronics	0.055	0.039	0.030	0.008	0.005	0.005
10.Motor vehicles, trailers & semi-trailers	0.071	0.051	0.039	0.012	0.008	0.008
11.Other industries	0.051	0.036	0.028	0.008	0.005	0.005
12.Contruction	0.061	0.049	0.042	0.026	0.024	0.024
13.Sale & repair of motor vehicles	0.058	0.043	0.034	0.013	0.010	0.010
14.Wholesale and retail trade	0.042	0.029	0.021	0.003	0.001	0.000
15.Air and water transport	0.058	0.045	0.038	0.020	0.018	0.017
16.Other transport	0.047	0.032	0.023	0.002	−0.001	−0.002
17.Telecommunications	−0.115	−0.136	−0.149	−0.179	−0.182	−0.190
18.Financial intermediation	0.012	−0.001	−0.009	−0.027	−0.029	−0.032
19.Activities auxiliary to financial intermediation	−0.014	−0.033	−0.044	−0.070	−0.073	−0.081
20.Real estate activities	0.136	0.107	0.090	0.051	0.046	0.046
21.Renting of machinery & equipment	0.020	0.001	−0.010	−0.036	−0.039	−0.041
22.Computer and related activities	−0.060	−0.073	−0.080	−0.098	−0.100	−0.104
23.Other business activities	0.027	0.014	0.007	−0.011	−0.013	−0.014
24.Other services	0.053	0.039	0.030	0.011	0.008	0.008
25.Public services	0.004	0.003	0.003	0.001	0.001	0.001
Total	0.038	0.026	0.019	0.002	0.000	−0.001
Leisure	0.040	0.027	0.020	0.002	0.000	−0.001
Max	0.136	0.107	0.090	0.051	0.046	0.046
Min	−0.115	−0.136	−0.149	−0.179	−0.182	−0.190
Variance	0.003	0.002	0.002	0.002	0.002	0.002
Range	0.250	0.243	0.239	0.230	0.228	0.236

(*continued*)

Table 6: (*continued*)

Panel B. Investment by foreign MNEs						
	Very rigid wages	Rigid wages	Reference scenario	Flexible wages	Very flexible wages	Full employment
1.Primary goods	0.044	0.029	0.020	−0.002	−0.004	−0.004
2.Energy	0.114	0.083	0.065	0.022	0.017	0.013
3.Food products	0.037	0.027	0.020	0.006	0.004	0.003
4.Beverages & Tobacco	0.095	0.074	0.062	0.032	0.029	0.028
5.Textiles products	0.077	0.058	0.047	0.021	0.018	0.018
6.Chemical products	0.052	0.038	0.030	0.012	0.009	0.009
7.Basic metals	0.056	0.040	0.031	0.009	0.006	0.005
8.Manufacture of metal products	0.047	0.034	0.026	0.008	0.006	0.006
9.Electronics	0.054	0.039	0.030	0.010	0.007	0.007
10.Motor vehicles, trailers & semi-trailers	0.064	0.045	0.034	0.009	0.006	0.005
11.Other industries	0.054	0.041	0.033	0.014	0.011	0.011
12.Contruction	0.061	0.050	0.043	0.028	0.026	0.026
13.Sale & repair of motor vehicles	0.057	0.042	0.034	0.014	0.012	0.011
14.Wholesale and retail trade	0.037	0.025	0.018	0.001	−0.001	−0.002
15.Air and water transport	0.062	0.050	0.043	0.027	0.025	0.024
16.Other transport	0.049	0.034	0.026	0.006	0.004	0.003
17.Telecommunications	−0.191	−0.212	−0.223	−0.251	−0.255	−0.261
18.Financial intermediation	−0.020	−0.032	−0.040	−0.057	−0.059	−0.061
19.Activities auxiliary to financial intermediation	−0.059	−0.077	−0.088	−0.112	−0.115	−0.122
20.Real estate activities	0.140	0.113	0.097	0.060	0.055	0.055
21.Renting of machinery & equipment	0.026	0.008	−0.002	−0.027	−0.030	−0.032
22.Computer and related activities	−0.113	−0.125	−0.132	−0.149	−0.151	−0.154
23.Other business activities	0.046	0.034	0.026	0.010	0.007	0.006
24.Other services	0.050	0.037	0.029	0.011	0.008	0.008
25.Public services	0.004	0.003	0.003	0.001	0.001	0.001
Total	0.035	0.024	0.018	0.002	0.000	0.000
Leisure	0.038	0.026	0.019	0.002	0.000	−0.001
Max	0.140	0.113	0.097	0.060	0.055	0.055
Min	−0.191	−0.212	−0.223	−0.251	−0.255	−0.261
Variance	0.005	0.004	0.004	0.004	0.004	0.004
Range	0.331	0.325	0.321	0.312	0.310	0.316

Table 6 (i. e., 1% change in ICT Capital Stock) allows to analyse the effects isolated from the sectoral asymmetric shock from the 2005–2014 change in ICT Capital Stock. Some of the characteristics of these results are common to the ones explained in the previous paragraph for the 2005–2014 shock:

- Sectoral asymmetric effects.
- The more flexible the wages, the more sectors are negatively affected.
- The increase in the size of the negative effect with more wage flexibility and, at the same time, the decrease in the size of the effect for the positively affected sectors.
- Most of the negatively affected sectors are Services while manufactures exhibit a pattern of job creation with ICT investment.

But the comparison between Panel A and B in Table 6 provides new insights on the relevance of firms' ownership. Firstly, the sectoral variance of the results is wider when the ICT investment is performed by MNEs with larger negative and positive sectoral effects. And secondly, the number of negatively affected sectors is smaller with foreign MNEs' ICT investment with flexible wages and tends to be larger with rigid wages. The scenario with very rigid wages shows 4 sectors with negative change in employment, while the very flexible wages scenario (and the full employment scenario) has 7 sectors with lower employment. In Panel A, with national firms' ICT investment, the scenario with very rigid wages shows 3 sectors with negative change in employment, while the very flexible wages scenario has 9 sectors.

7 Sensitivity analysis

To conclude, we present a sensitivity analysis of the previous results. They are presented in Table 7, for all the macroeconomic variables (namely, GDP, real wages, employment, unemployment rate and welfare). They are related to the reference scenario ($\beta = 1.5$) for both national firms and foreign MNEs' ICT investment; the full sensitivity analysis for all variables and scenarios is available from the authors upon request. We perform a change in some elasticities appearing in the model, which are alternatively doubled and halved. Those elasticities of substitution are considered the most relevant for the results and they are: (i) between non-ICT capital and the composite of ICT capital and labour; (ii) between labour and ICT capital; (iii) across final consumption goods in the welfare function.

Table 7: Sensitivity analysis on key elasticities of substitution.

	Shock: Real 2005–2014 change in ICT Capital Stock					
	GDP	Real wages	Employment	Unemployment rate		Welfare
				(%)	(p.p)	
REFERENCE SCENARIO (β = 1.5)						
National firms	1.52	0.65	0.8	−8.08	−0.74	1.6
Foreign MNEs	0.65	0.29	0.35	−3.41	−0.31	0.7
Elasticity of substitution between non-ICT capital and composite of ICT capital and labour (benchmark = 1.21)						
National firms - doubled	2.11	1.01	1.62	−13.09	−1.20	2.12
Foreign MNEs - doubled	0.91	0.45	0.71	−5.58	−0.51	0.93
National firms - halved	1	0.32	0.05	−3.58	−0.33	1.13
Foreign MNEs halved	0.42	0.15	0.03	−1.47	−0.13	0.48
Elasticity of substitution between labour and ICT capital (benchmark = 1.09)						
National firms - doubled	1.02	0.27	−0.2	−2.68	−0.25	1.19
Foreign MNEs - doubled	0.65	0.19	−0.07	−1.83	−0.17	0.74
National firms - halved	2.07	1.07	1.95	−14.25	−1.31	2.03
Foreign MNEs halved	0.59	0.32	0.58	−4.04	−0.37	0.6
Elasticity of substitution across final consumption goods (benchmark = 1)						
National firms - doubled	1.66	0.66	1	−9.53	−0.87	1.81
Foreign MNEs - doubled	0.72	0.29	0.44	−4.07	−0.37	0.79
National firms - halved	1.38	0.62	0.57	−6.56	−0.60	1.42
Foreign MNEs halved	0.59	0.28	0.25	−2.7	−0.25	0.61

All the results are robust in sign with respect to the elasticity of substitution between non-ICT capital and composite of ICT capital and labour, and show that the higher the elasticity, the larger the positive effect. With respect to the elasticity of substitution between labour and ICT capital, all the variables except employment are robust in sign, but all show the rationale: the easiest is to substitute directly ICT capital for labour (i. e. the larger this elasticity), the lower the effect in labour. The pattern of the results is also maintained in this case (national firms outperform foreign MNEs). Finally, the elasticity of substitution across final consumption goods is robust in sign and it seems to be the change in elasticity the least relevant for the results, although there are small quantitative changes.

All in all, the patterns identified in the simulations are still present despite changes in elasticities. Investment in ICT capital may crowd out labour in some sectors, but the aggregate impact is clearly positive for employment creation.

8 Concluding remarks

The aim of this paper is to measure in isolation the effects of digitalization on employment and other economic variables according to firms' ownership (i. e. national and foreign MNEs). We perform a general equilibrium analysis of increases in ICT investments using different specifications for (imperfect and perfect) labour markets and allowing for the substitution between labour and ICT capital in both types of firms. Our computable general equilibrium models differentiate the cost structures of the two types of firms assuming that capital is specific. The models break up the capital into ICT and non-ICT. Due to the lack of data to divide the ICT investments according to firms' ownership we performed two extreme simulations: (a) National firms are responsible for all the new ICT investment; (b) foreign MNEs are responsible for all the new ICT investment.

The growth of ICT gross fixed capital formation in Spain has been larger than the growth rate for other investment assets in the last two decades and also higher than in other Western countries. We perform the simulations of the increase in ICT investment with its real 2005–2014 data and also with a 1% homogeneous sectoral change. At the macroeconomic level, some conclusions have been derived from this exercise. Firstly, the macroeconomic effects of the ICT capital growth are positive in terms of GDP, employment, unemployment rate and welfare, as expected. Secondly, when the ICT investment is executed by national firms, the gains for the Spanish economy are around twice the gains than when foreign MNEs are the investors. The higher capital intensity of foreign MNEs with respect to national firms is the main force (but not the only one) driving this effect, and this result reinforces the idea that ICT investment is changing the pattern of job creation (UNCTAD 2017). Thirdly, the role of wage flexibility with respect to the unemployment rate is quantitatively relevant. The higher the wage flexibility, the larger the increase in real wages after the ICT capital growth and, consequently, the lower the employment creation. This increase in wages is also predicted in other approaches (e. g. Wolter et al. 2016).

The model also allows to observe some relevant results at the microeconomic level. Firstly, the sectoral employment does not expand in every sector. Despite the aggregate job creation, some sectors lose because a substitution effect between labor and capital prevails. Nevertheless, all the sectors improve their

output production levels. The higher the wage flexibility (leading to more sizeable wage increases), the larger the number of sectors negatively affected. Secondly, in general, the sectors losing employment are related to non-manufactures. So, this result would be in line with the job polarization hypothesis. Thirdly, who is the investing firm (i. e. national or foreign) is relevant also for final demand. The ICT investment according to type of firms impacts the prices of the goods in a different way. Given the pattern of consumption, if the ICT investment is done by national firms, the change in goods prices benefits more the final consumers. Finally, the national or foreign character of the firm also affects the variance of the changes in sectoral employment. Foreign firms generate less job creation in those sectors growing in employment and more job destruction in sector having job losses. Again, an important force explaining this result is that foreign MNEs are more capital intensive, in general, than national firms operating within the same sector.

The CGE approach has limitations. Its walrasian structure in an Arrow-Debreu framework does not incorporate a stochastic validation. Although some advances have been done (i. e., Dixon/Rimmer 2013), it is a hard task to accomplish in this type of model. The role of some exogenous parameters is also key and the lack of econometric estimations can condition or even bias the results. The way to minimize this is to check results through a large sensitivity analysis. We incorporate it in Section 7, although only a very small number of results from our full sensitivity analysis have been included.

From the previous results, some policy recommendations on ICT investment emerge. In order to enhance this job creating and welfare improving investment, note that the best outcome corresponds to investment performed by national firms (or the less capital-intensive firms). Nevertheless, even in an expansive framework, there are a few sectors negatively affected, normally more related to Services. Some short-term employment adjustment seems very plausible, so active labour policies should be addressed to mitigate this adjustment.

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Appendix 1: The models

As a general rule, the notation in the model is as follows: endogenous variables are denoted by capital letters, exogenous variables by capital letters with a bar, and parameters by small Latin and Greek letters. There are 25 (i, $j = 1,\ldots, 25$) production sectors and each sector produces one good. All endogenous variables, and the exogenous variables and parameters, are listed in Tables 8 and 9 below. The model's equations for the model with unemployment are as follows. At the end of the Appendix there is an explanation of the model with full employment. Note that this description does not distinguish production functions and variables between national and foreign firms. This has been done in order to clarify the presentation. Both types of firms share exactly the same equations and their differences are related to the data applied.

Table 8: Endogenous variables.

Symbol	Definition
A_i	Armington aggregate (total amount of goods supplied) of sector *i*
CF_i	Final domestic consumption of goods produced by sector *i*
CF_i^{PUB}	Final public consumption of goods produced by sector *i*
CF_i^{RC}	Final private consumption of goods produced by sector *i*
CPI	Consumer price index
EXP_i	Exports of sector *i*
FC	Factor of conversion of foreign currency into domestic currency
I_i	Investment (gross capital formation) in goods produced by sector *i*
II_{ij}	Intermediate inputs from sector *j* used by sector *i*
IMP_i	Imports from sector *i*
O_i	Production of sector *i* sold in the domestic market
OIT_i	Other indirect taxes revenue in sector *i*
P_{sav}	Savings shadow price
PA_i	Unit cost of the Armington aggregate of sector *i*
PLK_i	Unit cost of the composite of labour and ICT capital used in sector *i*
PO_i	Unit cost of the production of sector *i* sold in the domestic market
$PROFIT_i^A$	Unit profits for A_i (according to origin)
$PROFIT_i^{CET}$	Unit profits for A_i (according to destination)
$PROFIT_i^X$	Unit profits for X_i
PVA_i	Unit cost of the primary factors used in sector *i*
PX_i	Price of the goods produced by sector *i*
Q_c	Demand for aggregate consumption
Q_{cg}	Demand for aggregate consumption of goods
Q_l	Demand for leisure
Q_{sav}^{Priv}, Q_{sav}^{Pub}	Private and public demand for savings
$RNICT_i$	Specific non-ICT Capital rental rate in sector *i*
$RICT_i$	Specific ICT Capital rental rate in sector *i*
SOC_i	Revenue from social contributions paid by employers and employees of sector *i*
U	Unemployment rate
VAT_i	Value added tax revenue in sector *i*
W	Wage rate
WF	Welfare
X_i	Production of sector *i*
Y_{PUB}	Disposable income of the public sector
Y_{RC}	Disposable income of the representative consumer

Production

The nested technology presents constant returns to scale and a competitive pricing rule. Given that the top nest is a Leontief function, the zero-profit condition for sector *i* is:

$$PROFIT_i^X = PX_i\left(1 - oit_i^{II}\right) - c_{0i}PVA_i - \sum_{j=1}^{25} c_{ji}PO_j = 0 \ (i = 1, \ \ldots, \ 25) \tag{1}$$

Table 9: Exogenous variables and parameters.

Symbol	Definition
$\overline{FORSAV}$	Foreign savings
$\overline{KNICT_i^{PUB}}$, $\overline{KICT_i^{PUB}}$	Non-ICT and ICT Capital endowment of the public sector to produce good *i*
$\overline{KNICT_i^{RC}}$, $\overline{KICT_i^{RC}}$	Non-ICT and ICT Capital endowment of the representative consumer to produce good *i*
$\overline{L}$	Labour endowment
$\overline{NPTs}$	Net transfers from the representative consumer to the public sector
$\overline{PFX}$	World prices
$\overline{U0}$	Unemployment rate in the benchmark
$a_i, b, c_{0i}, c_{ji}, d_i, e_i, f_i$	Share parameters
oit_i^{II}, oit_i^{GKF}, oit_i^{CF}	Other indirect taxes rates, *ad valorem*, in sector *i*, levied on intermediate inputs, investment and final consumption, respectively
soc_i	Social contributions rates, *ad valorem*, in sector *i*
α_i, ζ_i, $_i$	Scale parameters
B	Flexibility of the real wage to the unemployment rate
ε_i	Elasticity of transformation in sector *i*
θ_i	Share parameter
σ_i^A	Armington elasticity of substitution in sector *i*
σ^{CL}	Elasticity of substitution between final consumption and leisure
σ^{KLK}	Elasticity of substitution between non-ICT capital and composite of labour and ICT capital
σ^{LK}	Elasticity of substitution between labour and ICT capital
τ_i	Elasticity of substitution across final consumption goods
τ_{sav}	Elasticity of substitution between consumption and savings

where, according to the nested structure, the unit cost of the value-added composite produced by sector *i* is a nested CES function of three factors: sector and firm specific non-ICT capital, sector and firm specific ICT capital and labour:

$$PVA_i = \frac{1}{\alpha_i}\left(a_i^{\sigma^{KLK}} WR_i^{1-\sigma^{KLK}} + (1-a_i)^{\sigma^{KLK}} RNICT_i^{1-\sigma^{KLK}}\right) (i = 1, \ldots, 25) \tag{2}$$

$$PLK_i = \frac{1}{\gamma_i}\left(f_i^{\sigma^{LK}} (1+soc_i)^{1-\sigma^{LK}} W^{1-\sigma^{LK}} + (1-f)^{\sigma^{LK}} RICT_i^{1-\sigma^{LK}}\right) (i = 1, \ldots, 25) \tag{3}$$

We assume that firms maximize profits and choose the optimal mix of national and imported goods, and that of domestic sales and exports. This leads to the following zero-profit conditions:

$$PROFIT_i^A = PA_i - \left(e_i^{\sigma_i^A} PX_i^{1-\sigma_i^A} + (1-e_i)^{\sigma_i^A} (\overline{PFX}FC)^{1-\sigma_i^A}\right)^{\frac{1}{1-\sigma_i^A}} = 0 \ (i = 1, \ldots, 25) \tag{4}$$

$$PROFIT_i^{CET} = PA_i - \frac{1}{\varsigma_i}\left(d_i^{-\varepsilon_i} PO_i^{\varepsilon_i+1} + (1-d_i)^{-\varepsilon_i} (\overline{PFX}FC)^{\varepsilon_i+1}\right)^{\frac{1}{\varepsilon_i+1}} = 0 \ (i = 1, \ldots, 25) \tag{5}$$

These zero-profit conditions are used to get derived demand functions, by applying the Shephard's lemma on cost functions.

Next, we introduce the corresponding market clearing equations, with demands and supplies showing in the left-hand and the right-hand side, respectively:

$$X_i\left(-\frac{\partial PROFIT_i^X}{\partial PO_j}\right) = II_{ji} \ (i, j = 1, \ldots, 25) \tag{6}$$

$$\left(\frac{\partial PROFIT_i^X}{\partial RNICT_i}\right) = \overline{KNICT_i^{RC}} + \overline{KNICT_i^{PUB}} \ (i = 1, \ldots, 25) \tag{7}$$

$$\left(\frac{\partial PROFIT_i^X}{\partial RICT_i}\right) = \overline{KICT_i^{RC}} + \overline{KICT_i^{PUB}} (i = 1, \ldots, 25) \tag{8}$$

$$\sum_{i=1}^{25}\left(\frac{\partial PROFIT_i^X}{\partial W}\right) = \left(\bar{L} - Q_l\right)(1-U) \tag{9}$$

$$A_i\left(-\frac{\partial PROFIT_i^A}{\partial PX_i}\right) = X_i \ (i = 1, \ldots, 25) \tag{10}$$

$$A_i\left(-\frac{\partial PROFIT_i^A}{\partial FC}\right) = IMP_i \ (i = 1, \ldots, 25) \tag{11}$$

$$A_i\left(-\frac{\partial PROFIT_i^{CET}}{\partial PO_i}\right) = O_i \ (i = 1, \ldots, 25) \tag{12}$$

$$A_i\left(-\frac{\partial PROFIT_i^{CET}}{\partial FC}\right) = EXP_i \ (i = 1, \ldots, 25) \tag{13}$$

$$X_i + IMP_i = O_I + EXP_i \ (i = 1, \ldots, 25) \tag{14}$$

$$I_i + \sum_{j=1}^{18} II_{ij} + CF_i = O_i (i = 1, \ldots, 25) \tag{15}$$

Consumption

The final demand functions are derived from the maximization of the representative consumer's nested welfare function:

$$WF = (Q_c)^{1-\tau_{sav}} \left(Q_{sav}^{priv}\right)^{\tau_{sav}} \tag{16}$$

subject to the budget constraints:

$$Y_{RC} = W\left(\bar{L} - Q_l\right)(1-U)(1-it) + \sum_{i=1}^{25} RNITC_i \overline{KNICT_i^{RC}} + \sum_{i=1}^{25} RICT_i \overline{KICT_i^{RC}} + \overline{NTPS} \tag{17}$$

$$Y_{RC} = P_{sav} Q_{sav}^{priv} + \sum_{i=1}^{25} PO_i \left(1 + oit_i^{CF}\right) CF_i^{RC} \tag{18}$$

and the nests in the welfare function are defined by:

$$Q_c = \left(b^{\sigma^{CL}} Q_{cg}^{1-\sigma^{CL}} + (1-b)^{\sigma^{CL}} Q_l^{1-\sigma^{CL}}\right)^{\frac{1}{1-\sigma^{CL}}} \tag{19}$$

$$Q_{cg} = \prod_{i=1}^{24} \left(CF_i^{RC}\right)^{\tau_i} \tag{20}$$

Consumption goods are purchased by the representative consumer and the public sector:

$$CF_i = CF_i^{RC} + CF_i^{PUB} \quad (i = 1, \ldots, 25) \tag{21}$$

The solution to the maximization problem yields the demand functions for savings, leisure, and final demand.

Public sector

The income of the public sector is given by:

$$Y_{PUB} = \sum_{i=24}^{25} RNITC_i \overline{KNICT_i^{PUB}} + \sum_{i=24}^{25} RICT_i \overline{KICT_i^{PUB}} + \sum_{i=1}^{25} (SOC_i + OIT_i) - \overline{NTPS} \tag{22}$$

where revenues come from several taxes:

$$SOC_i = Wsoc_i X_i \left(- \frac{\partial PROFIT_i^X}{\partial W} \right) \quad (i = 1, \ldots, 25) \tag{23}$$

$$OIT_i = PX_i oit_i^{II} X_i \left(- \frac{\partial PROFIT_i^X}{\partial PX_i} \right) + PO_i I_i oit_i^{GKF} + PO_i CF_i oit_i^{CF} \quad (i = 1, \ldots, 25) \tag{24}$$

The macro closure rule is:

$$Y_{PUB} = \sum_{i=1}^{25} PO_i \left(1 + oit_i^{CF}\right) CF_i^{PUB} + P_{sav} Q_{sav}^{pub} \tag{25}$$

Foreign sector, investment and savings

The macro closure of the model involves some other constraints related to investment and savings in this open economy:

$$\sum_{i=1}^{25} \overline{PFX} EXP_i + \overline{FORSAV} = \sum_{i=1}^{25} \overline{PFX} IMP_i \tag{26}$$

$$P_{sav} Q_{sav}^{priv} + P_{sav} Q_{sav}^{pub} + \overline{FORSAV} = \sum_{i=1}^{25} PO_i \left(1 + oit_i^{GKF}\right) I_i \tag{27}$$

Factor markets

The equilibrium in the capital market is given in (7) and (8), and the equilibrium in the labour market in (9), with some restrictions related to the unemployment assumptions:

$$\frac{W}{CPI} = \left(\frac{1 - U}{1 - \overline{U0}} \right)^{\frac{1}{\beta}} \tag{28}$$

$$CPI = \frac{\sum_{i=1}^{25} \theta_i PO_i}{\sum_{i=1}^{25} \theta_i \overline{PO_i}} \tag{29}$$

The full employment model does not incorporate the equations (28) and (29) and equation (9) has U equal to zero.

Appendix 2: Sectors in the model and their correspondences across different sectoral classifications

	Spanish Input-output Table (2005)	NACE Rev. 1	Nace Rev.2
1.Primary goods	1,2,3	01,02,05	01,02,03
2.Energy	8,9,10	23.04	19.35
3.Food products	12,13,14	15 (except 159)	10
4.Beverages & Tobacco	15.16	159.16	11.12
5.Textiles products	17,18,19	17,18,19	13,14,15
6.Chemical products	23.24	24.25	20,21,22
7.Basic metals	29.31	27.29	24.28
8.Manufacture of metal products	30	28	25
9.Electronics	32,34,35	30,32,33	26
10.Motor vehicles, trailers & semi-trailers	36	34	29,3311,3315,3316,3317
11.Other industries	4,5,6,7,11,20,21,22,25,26,27,28,33,37,38,39	10,11,12,13,14,20,21,22,25,26,31,36,37,41	05,06,07,08,09,16,17,18,23,27,30,31,36
12.Contruction	40	45	41,42,43
13.Sale & repair of motor vehicles and automotive fu	41	50	45
14.Wholesale and retail trade	42.43	51,52	46,47
15.Air and water transport	48.49	61,62	50.51
16.Other transport	46,47,50,51	60,63	49,52,79
17.Telecommunications	52	64	53,60,61
18.Financial intermediation	53,54	65,66	64,65

(*continued*)

(*continued*)

	Spanish Input-output Table (2005)	NACE Rev. 1	Nace Rev.2
19.Activities auxiliary to financial intermediation	55	67	66
20.Real estate activities	56	70	68
21.Renting of machinery & equipment	57	71	77
22.Computer and related activities	58	72	58,62,63,95
23.Other business activities	60	74	69,70,71,73,74,78,80,81,82
24.Other services	44,45,59,61,62,63,64,65,66,71,72	55,56,73,80,85,90,91,92,93	37,38,39,55,56,59,72,75,85,86,87,88, 90,91,92,93,94,96
25.Public services	67,68,69,70	75,80,85,90	84,97